2893/ 1

Indian Journal of Chemical Technology
Vol. 15, September 2008, pp. 457-461

Greaseproof paper from Banana (*Musa paradisica* L.) pulp fibre

T Goswami, Dipul Kalita* & P G Rao

North East Institute of Science and Technology (CSIR), Jorhat 785 006, India
Email: dipkalita_2001@yahoo.co.in

Received 20 September 2007; revised 2 May 2008

Utilization of banana pulp fibre for producing greaseproof paper has been investigated. The morphological characteristics of plant and fibre, chemical constituents of the sheath, characteristics of pulp and physical strength properties of hand sheet of 45±5 gsm made from banana pulp alone or in combination with bamboo pulp fibre are presented. Results of the laboratory investigation show that *Musa paradisica* contain high quantity of gums and mucilage inside the sheaths. The pentosan content (13.5%) may also impart the greaseproof properties. The drainage time of the banana pulp increases with the increase of beating time. At 80^0SR freeness, the pulp becomes hydrated and forms a jelly like stock. The paper made out of this hydrated pulp stock shows the characteristics of greaseproof paper with burst index 6.10 kpam^{2}g^{-1}, tear index 7.00 mNm^{2}g^{-1} and tensile index 51.2 N mg^{-1} with very good blister and oil resistibility. The physical strength properties of the paper may further be enhanced by incorporating 20% bamboo pulp beaten up to 85^0SR freeness and mixed with banana semi bleached pulp stock beaten up to 85^0SR freeness.

Keywords: Banana sheath, Hydration, Hemicellulose, Greaseproof paper, *Musa paradisica*

Banana is an important fruit crop which belongs to the genus *Musa*. It grows wild and also cultivated on a large scale as a field crop as well as a backyard crop in households. In India, banana is cultivated in about 1,86,000 hectare of land[1]. The plant shows luxuriant growth in rich well-drained soil with ample moisture and decaying organic matter. It can also flourish on light sandy or gravelly soil as well as on stiff but well drain clay, if the soil is fertile and facilitities for irrigation are available[2].

The pseudostem portion of the plant contains fibre suitable for making ropes and twines[3]. Extraction of certain species of banana fibre and its industrial application has also been reported[4]. The fibre is located primarily adjacent to the outer surface of the leaf sheath. Well cleaned and brushed decorticated whole leaf sheath[5] yield 80-85% long (4-6 mm), slender (mean width 17-21 μm) fibres.

Greaseproof paper is a type of non-absorbent paper that is impermeable to oil or grease and can be used for various purposes in the kitchen like layering fragile foods, wrapping food for storage and for lining cake tins. It is suitable for use in fridges, freezers and microwave ovens. It can be used to line baking trays, to wrap foods for packed lunches and to wrap fatty foods such as butter, cheese, smoked fish, cold meats and salami. Use of greaseproof paper to make jam pot covers and lids and for separating food into individual portions for freezing is also reported. Greaseproof paper is made from wood pulps which are highly hydrated so that the resulting paper is resistant to oil and grease. The timber resources used to make wood pulp are referred to as pulpwood. Wood pulp generally comes from softwood trees such as spruce, pine, fir, larch and hemlock, and also some hardwoods such as eucalyptus and birch.

In recent years, with the growing shortage of wood from the forest, the search for alternative fibre producing plant material has been initiated in many countries of the world. The generation of fast growing high biomass yielding plant is thought to be one of the solutions to meet the shortage of cellulosic material[6-10]. However, certain agricultural plants producing higher biomass are found to be suitable substitute for certain fibre based industries[11]. Among them banana plant may serve partly as an alternative resource in fibre based industries.

The banana fibres possess good physical strength properties. The higher pentosan content together with gums and mucilage in the sheath of certain species of banana plant may be a suitable source for producing greaseproof paper. Although, reports are available on utilization of banana fibre for textile, pulp and paper making[12], but no reports are available so far on the development of greaseproof paper using banana sheath fibre. Considering the higher pentosan, gums and mucilage contents in the sheath of *Musa paradisica* plant, a detailed investigation was undertaken to study the possibility of making greaseproof paper from this plant and the results obtained from this investigation are presented in this communication.

Experimental Procedure

Materials

The banana plant (*Musa paradisica* L.) selected for the present work was collected from the village nearby NEIST, Jorhat, Assam. The leaves and roots were discarded and only the stem portion was used in the present investigation. The sheaths were removed manually from the stem and washed with fresh cold water. The sheaths were converted to strips of 90 cm length and then crushed in a three-roll crusher to remove the excess water. The crushing action reduces the moisture content of the sheath up to 45-50%. The crushed sheaths were then air-dried.

For blending study, bleached bamboo (*Bambusa tulda*) pulp with 80-85% cellulose, 11.5% pentosan, 70% brightness and 10.5 cp CED viscosity was procured from Hindustan Paper Mill, Nagaon, Assam. All the chemicals and reagents used in the present investigation were of analytical grade.

Pulping of banana sheath

For pulp making, crushed sheath material was taken in a stainless steel vessel and digested under pressure free condition. Three types of pulping processes such as soda, kraft and water prehydrolysis soda pulping were conducted to extract the fibres maintaining bath ratio at 1:8 and varying cooking time 2-3 h at boiling temperature depending upon the cooking conditions. The average pulp yield, kappa number, pulp brightness and viscosity were determined as per the TAPPI standard methods[13]. Bleaching was done by single stage hypochlorite treatment using calcium hypochlorite solution which was given at 3.0 - 4.2% total chlorine with 91.5 - 97.2% chlorine consumption maintaining pulp consistency at 10% for 80 min at 35-40°C with occasional stirring. The *p*H was maintained at 10.

The brightness of the pulp was measured using Digital Reflectance Meter (Universal-710 Model) on the basis of MgO=100.

Paper hand sheet making

Semi-bleached pulps obtained from banana sheath were beaten in a laboratory valley beater to different degrees of freeness (45, 55, 65, 75, 85 and 90°SR (Schopper-Reigler) at 1.25% consistency. Hand sheets of 45±1 gm^{-2} were made in a British Standard Laboratory hand sheet former using pulp stock beaten to different freeness levels. The sheets were then dried in oven and kept in PVC bags for subsequent study.

Analytical

Proximate chemical analysis of sheath

For determination of chemical constituents of the sheath, air-dried strips were cut into chips of 3 cm length and dried in an oven. The dried chips were converted to powder in a Willey mill. The powdered material passed through 40 BS mesh and retained on 60 BS mesh was taken for proximate chemical analysis adopting TAPPI standard method.

Fibre morphology

The morphological properties of the pulp fibre were studied in Dokuval photomicroscope. For determination of morphological characteristics of fibres, a small portion of semi bleached fibre was taken and disintegrated for sometime to make the fibre free from bundles. The bundle free fibres were taken and studied under microscope at different magnifications. Fibre length (L), diameter (D) fibre wall thickness (W) and lumen diameter (d) of well-disintegrated pulp fibre were measured.

Scanning electron microscopy (SEM)

A portion of the disintegrated semi bleached pulp fibre was taken and mounted on specimen holder with the help of electro conductive tape. The samples were coated with gold in an ion-sputter coater (JFC 100, JEOL, Japan) in low vacuum with a layer 150-200 nm thick. The observation was made in a JEOL, JSM-35M-35CF electron microscope at an accelerating potential of 15 KV and micrographs were taken.

Paper properties

The dried paper sheets were conditioned at 65% relative humidity and 27°C for 2 h and then tested for various physical strength properties such as tensile index, bursting index, double fold, tear index, blister and oil permeability as per TAPPI standard method.

Results and Discussion

Table 1 shows the hemicellulose content (%) in different species of banana plants. Among the four different species *viz. Musa cavendish, Musa paradisica, Musa velutina* and *Musa balbisiana,* the hemicellulose content was highest (17.5%) in *M. parasidica.* Based on highest hemicellulose content, *M. paradisica* plant was selected for further investigations.

The chemical constituents of banana plants are shown in Table 1. The *M. paradisica* plant contains 59.18% of cellulose along with 17.5% of hemicellulose. Alpha-cellulose content of the plant was 54.6% while ash and lignin content were found to be 1.4 and 18.2% respectively. The chemical constituents of *Musa paradisica* were comparable to that of some conventional paper making raw materials.

Table 2 shows the pulp yield in different pulping process and also the respective hemicellulose content in the pulp. It has been observed that water prehydrolysis soda process shows comparatively higher pulp yield (52.4%) with 15.3% hemicellulose in the pulp. From the other two pulping processes such as kraft and soda process, the pulp yield was 50.4 and 48.8% and hemicellulose content 15.8 and 14.3% respectively.

Physical properties *viz.* pulp yield, brightness, cellulose and hemicellulose content, kappa number, viscosity etc. of semi bleached pulp are recorded in Table 3. The yield of unbleached pulp was 50.8% with kappa number of 25. The hemicellulose content of the semi bleached pulp was 17.5%. The yield of semi bleached pulp was 48.4% when single stage hypochlorite treatment was used. The initial freeness of the pulp was 15°SR. The final freeness at which the pulp gets hydrated and shows the properties of greaseproof paper was 80°SR.

Table 4 shows the morphological properties of pulp fibres. The average fibre length and diameter were 1.55 mm and 22 μm respectively with average lumen diameter and cell wall thickness 14.2 and 5.5 μm. Rankle ratio and slenderness ratio were found to be 0.77 and 70.5 respectively. The morphological index of the fibre signifies the suitability of *M. paradisica* fibre for making good quality pulp in addition to produce greaseproof paper.

Physical strength properties of semi-bleached paper made from *M. paradisica* at different degree of freeness and also a set of experiment with a mixture of bamboo and banana pulp at 25:75 ratio are reported in Table 5. It has been observed that banana pulp shows greaseproof properties at 80°SR freeness and the beating time required to get 80°SR freeness was 180 min. The physical strength properties of paper sheet such as tensile index, burst index and tear index were reported 51.20 N mg^{-1} and 6.21 $kgpam^2g^{-1}$ and 7.00 mNm^2g^{-1} respectively with very good blister and oil resistance properties. As the greaseproof paper requires good physical strength properties, therefore it can further be enhanced by incorporating bamboo pulp beaten up to 85°SR freeness and mixed

Table 1—Proximate chemical analysis of Banana plant

	Musa cavendish	*Musa paradisica*	*Musa velutina*	*Musa balbisiana*
Solubility (%)				
Cold water	2.60 [a] ± 0.18 [b]	2.75 ± 0.15	2.75 ± 0.57	2.40 ± 0.62
Hot water	3.15 ± 0.51	3.10 ± 0.58	2.85 ± 0.51	3.20 ± 0.47
1% NaOH	25.35 ± 2.78	28.65 ± 2.67	26.70 ± 2.65	28.00 ± 2.34
Alcohol benzene	2.80 ± 0.22	3.10 ± 0.27	2.70 ± 0.41	2.00 ± 0.32
Cellulose (%) (Cross & Bevan)	57.80 ± 2.54	59.18 ± 2.71	58.75 ± 2.46	62.2 ± 2.43
Hemicellulose (%)	15.50 ± 1.43	17.50 ± 1.57	16.50 ± 1.27	15.2 ± 1.28
Lignin (%)	17.25 ± 1.49	18.21 ± 1.04	17.50 ± 1.52	18.0 ± 1.27
Ash content (%)	1.60 ± 0.03	1.40 ± 0.04	1.80 ± 0.08	2.50 ± 0.46
Alpha Cellulose (%)	53.75 ± 4.98	54.60 ± 4.82	55.00 ± 4.58	54.20 ± 3.98
Silica (%)	0.70 ± 0.01	0.42 ± 0.01	0.60 ± 0.01	0.80 ± 0.01

[a]Values are means of five observations (n=5)
[b]Standard error of means

Table 2—Pulp yield and hemicellulose content at different pulping process

Pulping process	Pulp yield (%)	Hemicellulose content in pulp (%)
Kraft pulping	50.4	$15.8^{a} \pm 1.37^{b}$
Water prehydrolysis + NaOH	52.5	15.3 ± 1.58
Soda pulping	48.8	14.3 ± 1.26

[a]Values are means of five observations (n=5)
[b]Standard error of means

Table 3—Physical characteristics of semi bleached pulps obtained from *Musa paradisica*

Parameters		Value
Pulp yield%	Unbleached	$50.8^{a} \pm 2.14^{b}$
	Semi bleached	48.4 ± 1.65
Brightness (%)		52.5 ± 2.67
Hemicellulose (%)		17.5 ± 1.30
Cellulose (%)		59.18 ± 2.74
Kappa number		25 ± 3.10
CED* viscosity (cp)		7.5 ± 1.17
Initial pulp freeness (^{0}SR*)		15 ± 1.08
Final pulp freeness (^{0}SR)		85 ± 4.67

CED- Cupriethylene diamine, SR-Schopper Riegler
[a]Values are means of five observations (n=5)
[b]Standard error of means

with banana pulp at a ratio 80:20. The mixture of banana and bamboo pulp at 80:20 ratio gives greaseproof paper with tensile index 53.20 N mg^{-1}, burst index 6.42 kpam^{2}g^{-1} and tear index 4.40 mNm^{2}g^{-1}. These results are comparable with the greaseproof paper made from water hyacinth (tensile index 50.80 N mg^{-1}, burst index 4.90 k pa m^{2}g^{-1} and tear index 3.86 mNm^{2}g^{-1})[14].

Figure 1 shows the electron micrographs of banana pulp fibres. There are two types of fibre visible under microscope. Some fibres are narrow and others are

Table 4—Morphological properties of banana (*M. paradisica*) pulp fibres

Properties		Value
Fibre length, L (mm)	Maximum	$6.50^{a} \pm 0.87^{b}$
	Minimum	0.65 ± 0.01
	Average	1.55 ± 0.07
Fibre width, D (μm)	Maximum	26 ± 2.14
	Minimum	15 ± 1.37
	Average	22 ± 1.59
Average Lumen width d, (μm)		14.2 ± 0.12
Average cell wall thickness w, (μm)		5.5 ± 0.23
Runkel ratio, 2 W/d		0.77 ± 0.24
Slenderness ratio, L/D		70.5 ± 0.16

[a]Values are means of five observations (n=5)
[b]Standard error of means

Table 5—Physical strength properties of banana (semi bleached) and bamboo pulp sheets at different degrees of freeness

Sample	Degree of freeness (°SR)	Beating time (min)	Burst index (kPa m^{2}g^{-1})	Tear index (mN m^{2}g^{-1})	Tensile index (N mg^{-1})	Double fold no.	Oil transudation period (s)	Blister
Musa paradisica	45	30	4.51	9.10	47.76	120^{+}	-	Nil
	55	70	4.75	8.78	48.10	150^{+}	-	-do-
	65	120	5.23	8.12	49.68	160^{+}	-	-do-
	75	160	5.86	7.56	50.53	200^{+}	-	-do-
	80	180	6.21	7.00	51.20	260^{+}	1800^{+}	Very good
	85	240	6.10	6.84	52.00	280^{+}	1800^{+}	Very good
M. paradisica	45	40	4.35	7.86	49.60	180	-	Nil
	55	80	4.60	6.10	50.20	200	-	-do-
+	65	125	4.85	5.75	51.46	200	-	-do-
B. tulda	75	150	5.93	5.00	52.85	250^{+}	-	-do-
	85	180	6.42	4.40	53.20	300^{+}	1800^{+}	Very good
80:20	90	225	6.63	4.00	53.75	380^{+}	1800^{+}	Very good

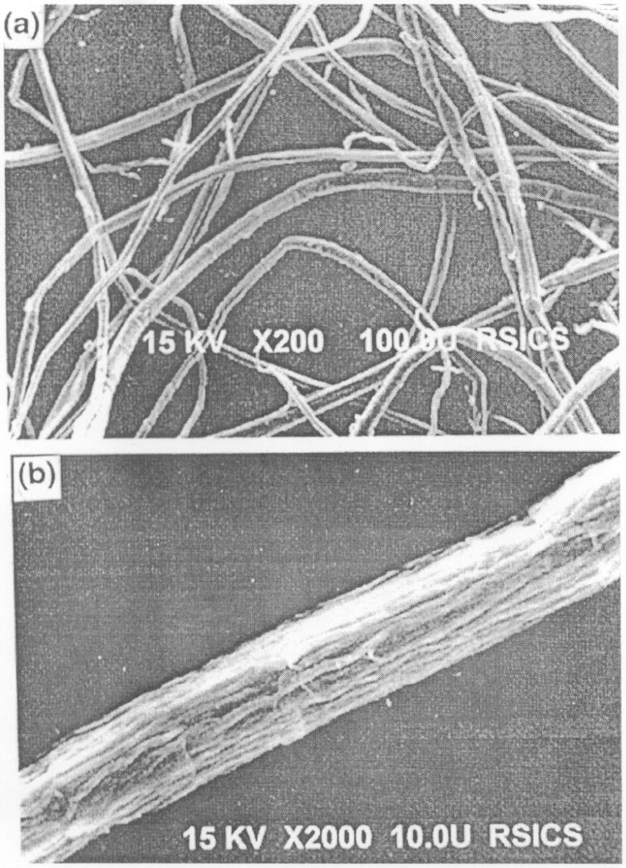

Fig. 1—SEM of (a) banana pulp fibres (b) single fibre

comparatively wider. Cell walls are distinctly visible (Fig. 1a). The fibrillar arrangements are linear. There are occasional void spaces between the fibrilles (Fig. 1b). There are some pores and some cracks visible in the fibres.

Conclusion

From the study, it may be concluded that banana (*Musa paradisica*) fibre may be a potential raw material for making greaseproof paper. It can produce a good quality greaseproof paper with all desired properties. The paper properties can be further enhanced by incorporating 20% bamboo pulp to banana pulp.

Acknowledgement

The authors are thankful to Dr. P G Rao, Director, North East Institute of Science and Technology (CSIR), Jorhat for his kind permission to publish this paper.

References

1 Brahma Iyer P, Vivekanandan M V, Sreenivasan S & Krishna Iyer K R, *The Indian Text J,* 105(1) (1995) 42.
2 *The Wealth of India, Raw Materials*, Vol. 6 [Publication and Information Directorate (CSIR), New Delhi], 1962.
3 Saikia D C, Goswami T & Saikia C N, *J Sci Ind Res*, 56 (1997) 408.
4 Anon, *Report of M Visvesvaraya Industrial Research and Development Centre*, Bombay, 1986.
5 Escolano J O, Valmonte A D & Tamolang F N, *Conf on Wood Quality and Utilization of Tropical Species,* held at Forpridecom College, Laguna, Oct. 30 – Nov. 3, (1978) Philipines.
6 Atchison J E & Collins T T, *Worldwide Development of Kenaf; TAPPI Non-wood Plant Fibre Pulping,* Progress Report No. 7 (TAPPI Press, Atlanta, USA), 1976, 15.
7 Watson A J, Davies G W & Gartsid G, *APPITA*, 30 (1976) 129.
8 Clark T F, Cunningham R L & Wolff I A, *TAPPI*, 54 (1971) 63.
9 Mohan Rao N R, Kishore H, Murthy K S, Kulkarni A G & Pant R, *IPPTA*, 20 (1983) 17.
10 Singh S P, Darbal S K, Naithani S & Singh S V, *IPPTA*, 15(2) (2003) 67.
11 Saikia C N, Goswami T & Ali F, *Wood Sci Technol,* 31 (1997) 467.
12 Goswami T & Saikia C N, *Bioresource Technol*, 50 (1994) 235.
13 TAPPI *Standard and Suggested Methods* (Technical Association of Pulp and Paper Industry, TAPPI Press, Atlanta, USA), 1980, 200.
14 Ghosh S R, Saikia D C, Goswami T, Chaliha B P & Baruah J N, *Proc Int Conf on Water Hyacinth*, Hyderabad, India Feb 7-11 (1983) 436.